ACRP Report 127: A Guidebook for Mitigating Disruptive WiFi Interference at Airports

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Principal Investigator

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Lead Engineer

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- Chair:
  - ANSI ASC C63 SC6 – Spectrum Management
  - ANSI C63.27 – Wireless Coexistence Testing
  - IEEE 1900.2 – Wireless Coexistence Analysis

- * SPC is now SPC-Federal, LLC, a subsidiary of ECS-Federal, LLC

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ACRP Report 127 Oversight Panel

- *John Newsome*, Greater Orlando Aviation Authority, FL. (Chair)
- *Pamela E. Bell*, Ross & Baruzzini, Inc., Bellevue, WA
- *John A. Buckner*, Salt Lake City Department of Airports, Salt Lake City, UT
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- *Jeffrey Rae*, United Airlines, Chicago, IL
- *Dawoud Stevenson*, Savannah Airport, Savannah GA
- *Kiem Hoang*, FAA Liaison
- *Alvin Logan*, FAA Liaison
- *Aniel Patel*, Airports Council International-North America Liaison

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Problem – Assuring Reliability of Wireless Services at Airports

- How to ensure reliability and acceptable performance of wireless services in the face of growing spectral congestion
- Potential problems:
  - Radio frequency (RF) interference
  - Equipment interoperability
  - Network congestion
  - Poor coverage
  - Reliability, priority, and security (for airport operations)
- Environment:
  - There are a few bands that are congregating points for a wide variety of services
  - Some of the most congested bands are open access and under FCC rules *airports cannot regulate use of these bands or prohibit travelers and vendors from using their own equipment*

ACRP Report 127:
A Guidebook for Mitigating Disruptive WiFi Interference at Airports

- Quantifies extent and magnitude of interference problems
- Identifies best technical and business practices to provide accessible service with adaptable bandwidth for all stakeholders
- Recommends a cooperative approach via communication and collaboration among parties to maximize benefits
- References a design adaptable to all airport environments (small, medium, large) to meet needs of all stakeholders
- Provides techniques for identifying and resolving interference outside reference design
- Enables a strategic vision that addresses potential impacts due to increasing demand, evolving technologies, and new requirements
- Addresses total cost of ownership and return on investment
- Published 2015

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Research Approach

- Defined the problem:
  - What is RF interference and its impact on WiFi services
  - Understanding that WiFi services are transitioning from being a high-end consumer amenity used by relatively few passengers to services now expected to be available for all passengers as well as businesses and airport operations
- System approach:
  - Developed an RF interference primer, quantified the RF interference problem, and identified techniques to mitigate RF interference
  - Queried airports regarding their WiFi experience, capacity, and performance
    - Developed survey for 18 airports
    - Visited nine airports
- Provided a WiFi strategy that supports communications and collaboration among all stakeholders and addresses increased demand, evolving technologies, available WiFi tools, and new requirements

Research Results

- A few bands, particularly those used by WiFi, are heavily used and increasingly congested.
- Data traffic and wireless applications are growing, resulting in increased congestion in the future.
- The importance of WiFi and wireless services in general has always been important to airports but is becoming even more important and important to a growing number of areas of airport operations.
- Airports generally have sub-contracted wireless network management and as a result have limited expertise or experience with network management.
- Airport Growth trends in spectral congestion needs to be monitored so that management plans can anticipate rather than respond to growing congestion.

Results – Understanding RF Interference

- RF interference versus daily morning and evening commute - limited roads and rail choices creates recurring congestion and regular accidents.
- Spectrum use is similar the morning commute: spectrum users go to the same few bands and even the same few channels in those bands.
  - There are good reasons, but it creates spectral congestions and interference
  - Congestion has to be managed, it is difficult to prevent (think of HOV lanes vice telling people they cannot go to work in the morning)
- A wireless network is not a wired network without wires, it has its own dynamics and characteristics. Managing wireless networks is its own specialty

Results – Understanding RF Interference

- RF interference associated with “unlicensed” WiFi spectrum – involves dealing with several different issues
- Case study results:
  - Poor understanding of the range and variation of indoor RF environments
  - Dominate source of WiFi interference is from other WiFi devices.
  - Strong correlation between band crowding and interference
  - Co-location of WiFi and cellular network antennas
  - Technology changes – older systems inability to properly interface with newer systems
  - Customer complaints were major metric to determine performance quality
- Proper network design and management can eliminate potential RF interference
- Stakeholder cooperation can improve planning, performance, and reduce interference

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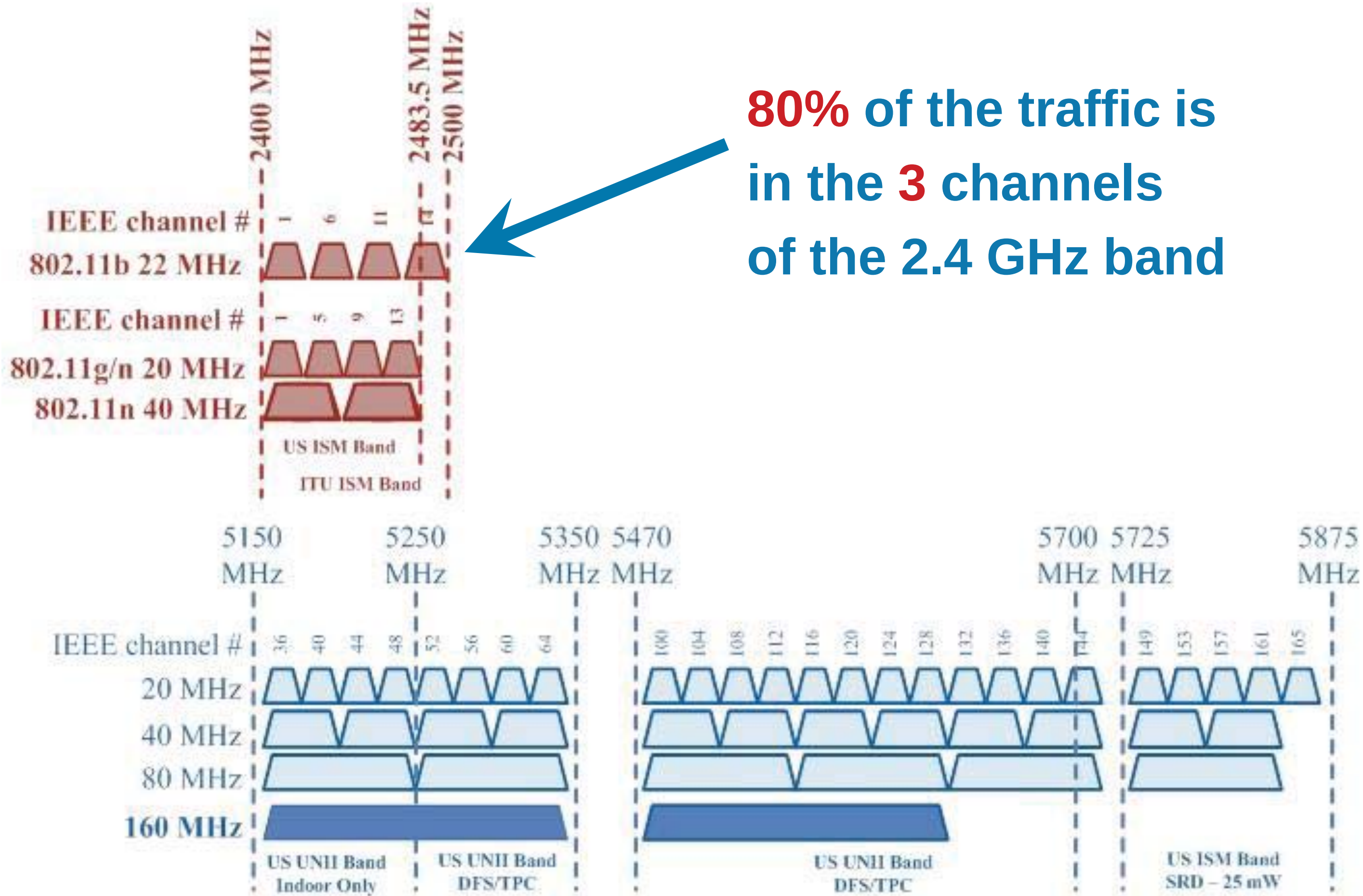
Spectrum Allocation
2.4 and 5 GHz WiFi Channels



80% of the traffic is in the **3** channels of the 2.4 GHz band

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Packet Retransmission Rates

Date (YR-MO-DAY)	Location	2.4 GHz Band - Retransmission Rate (%)													
	Channels:	1	2	3	4	5	6	7	8	9	10	11	12	13	14
140112	Killeen Airport Food Court	0.00%	0.00%	0.00%	0.00%	0.00%	9.61%	0.95%	0.00%	0.00%	0.00%	0.19%			
140112	DFW Gate A36	0.55%	0.00%	0.00%	0.00%	0.00%	2.59%	0.00%	1.30%	0.00%	0.00%	7.88%			
140112	DFW Gate D20	0.96%	0.00%		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
140112	DFW Gate E21	2.22%	0.00%	0.00%	0.00%	0.00%	2.83%	0.00%	0.00%	0.00%	0.00%	3.10%			
140115	DCA Gate 30 & Food Court	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.36%	4.94%	0.00%	0.00%	
140115	DCA Gate 27 & Food Court	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	14.41%			
140115	DCA Gate 25	3.14%	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.00%	0.00%	0.00%	5.20%			
140115	DCA Gate 28	0.96%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	3.55%			
140115	DFW Gate B18	0.00%	0.00%	0.00%	0.00%	0.00%	0.52%	0.00%	0.00%	0.00%	0.00%	2.17%			
140119	Austin near Terminal Door	0.23%	0.00%	0.00%	0.00%	0.00%	2.63%	0.00%	0.00%	0.00%	0.09%	1.95%			
140119	Austin Gate 12	6.78%	1.40%	3.97%	0.00%	0.00%	0.77%	0.00%	0.00%	6.38%	1.01%	4.99%			
140119	DCA Gate 2		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	3.88%			
140119	DCA Gate 9 - 1st Sample	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.14%	4.18%	0.00%	0.00%	
140119	DCA Gate 9 - 2nd Sample	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	12.42%			

Key

Blank – No transmission detected

0.00% – Data transmitted without errors

< 5% – Less that 5% retransmission rate

> 5% – More than 5% retransmission rate

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Channel Utilization (% Occupancy)

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Date (YR-MO-DAY)	Location	2.4 GHz Band - Channel Utilization (%)													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
130322	Atlanta Gate B22	8.1	10.2	1.6	12.9	13.3	12.4	10.2	7.2	5.0	4.5	3.4	2.5	1.5	0.2
130816	Chicago O'Hare Gate H5	7.1	7.3	5.9	4.7	5.0	5.1	5.1	5.2	7.2	9.0	9.0	8.0	5.1	0.1
130313	Nashville Gate A1	8.1	8.9	9.1	8.3	8.0	7.8	7.5	11.3	17.4	22.8	23.9	20.7	13.4	0.8
130814	DFW Gate A15	6.5	7.1	6.3	5.9	4.0	3.9	3.8	5.4	8.1	10.4	10.5	9.0	5.3	0.1
130509	Newark Gate A16	36.0	41.9	40.5	37.9	33.8	28.8	23.7	25.5	29.8	35.9	37.7	33.3	21.2	1.7
130403	Orange County Gate 14	11.9	11.4	8.1	4.1	4.1	4.3	4.1	3.2	1.6	1.1	0.9	0.7	0.4	0.1
130906	Austin Gate 8	6.8	7.3	7.3	8.8	10.1	10.4	10.4	16.6	24.0	32.5	35.6	30.6	21.1	0.8
131112	Austin Gate 9	14.3	14.3	12.0	6.9	6.2	6.1	4.6	3.1	5.4	7.0	6.8	6.5	3.6	0.6
131112	Midway Gate B2	15.3	16.0	13.2	10.5	9.7	9.7	10.5	11.8	13.4	16.3	16.6	13.1	8.8	0.7
131029	DEN Gate C33	21.0	23.5	21.6	21.3	19.3	15.9	14.0	12.9	12.8	15.6	16.4	14.8	9.8	0.6
131029	DEN Gate A37	7.0	6.7	5.8	7.9	9.3	9.7	9.7	7.3	4.8	4.5	4.4	4.2	2.6	0.5
131023	MSP Gate F1	66.1	63.9	58.5	49.9	37.2	28.5	17.0	10.3	8.8	9.7	10.1	8.9	6.1	0.8
131023	MSP Gate D4	11.0	11.6	11.6	11.4	11.2	11.1	10.7	8.9	8.6	9.9	9.8	9.0	5.5	0.4
131023	DEN Gate C40	10.7	11.3	10.3	10.1	13.0	14.4	13.9	13.0	16.4	20.4	20.7	19.8	12.8	0.4
131023	Copenhagen Gate C4	2.7	2.8	1.8	2.8	4.0	4.4	4.4	4.2	3.5	3.0	2.9	2.4	1.3	0.1
131023	Copenhagen Gate A2	5.7	5.2	6.3	7.1	7.3	8.1	7.3	4.8	2.9	1.4	1.1	0.8	0.5	0.0
140112	Killeen Airport Food Court	7.7	7.2	9.4	14.4	20.9	24.9	22.9	16.0	8.1	1.2	1.0	1.0	0.9	0.6
140112	DFW Gate A36	1.9	1.9	1.6	1.4	1.4	1.4	1.4	1.3	1.3	1.4	1.3	1.2	1.1	0.7
140112	DFW Gate D20	7.6	7.2	5.3	4.3	4.1	4.6	4.6	4.1	3.2	1.9	1.7	1.7	1.3	0.6
140112	DFW Gate E21	0.3	0.4	0.9	2.3	3.6	3.8	3.6	3.3	2.8	3.7	4.1	4.1	3.4	1.5
140113	NSF Keck Center Room 110	15.0	15.1	10.5	6.2	4.4	4.6	5.0	6.9	11.3	14.8	15.0	14.2	9.8	3.0
140115	DCA Gate 30 & Food Court	11.5	14.5	14.0	15.7	15.1	12.5	11.0	13.9	21.9	32.6	35.1	32.2	21.7	0.8
140115	DCA Gate 27 & Food Court	4.4	5.8	6.1	8.3	8.1	6.6	6.0	10.4	16.7	21.5	23.7	20.6	11.9	0.1
140115	DCA Gate 25	1.7	2.0	2.3	2.8	3.5	3.6	3.8	8.1	15.6	24.4	26.1	23.4	15.9	0.4
140115	DCA Gate 28	4.0	4.6	6.0	11.1	15.2	15.4	15.2	14.5	17.9	24.7	26.0	25.1	17.0	1.4
140115	DFW Gate B18	17.6	15.3	11.0	6.6	2.6	2.9	2.6	1.8	1.1	0.6	0.5	0.4	0.2	0.1

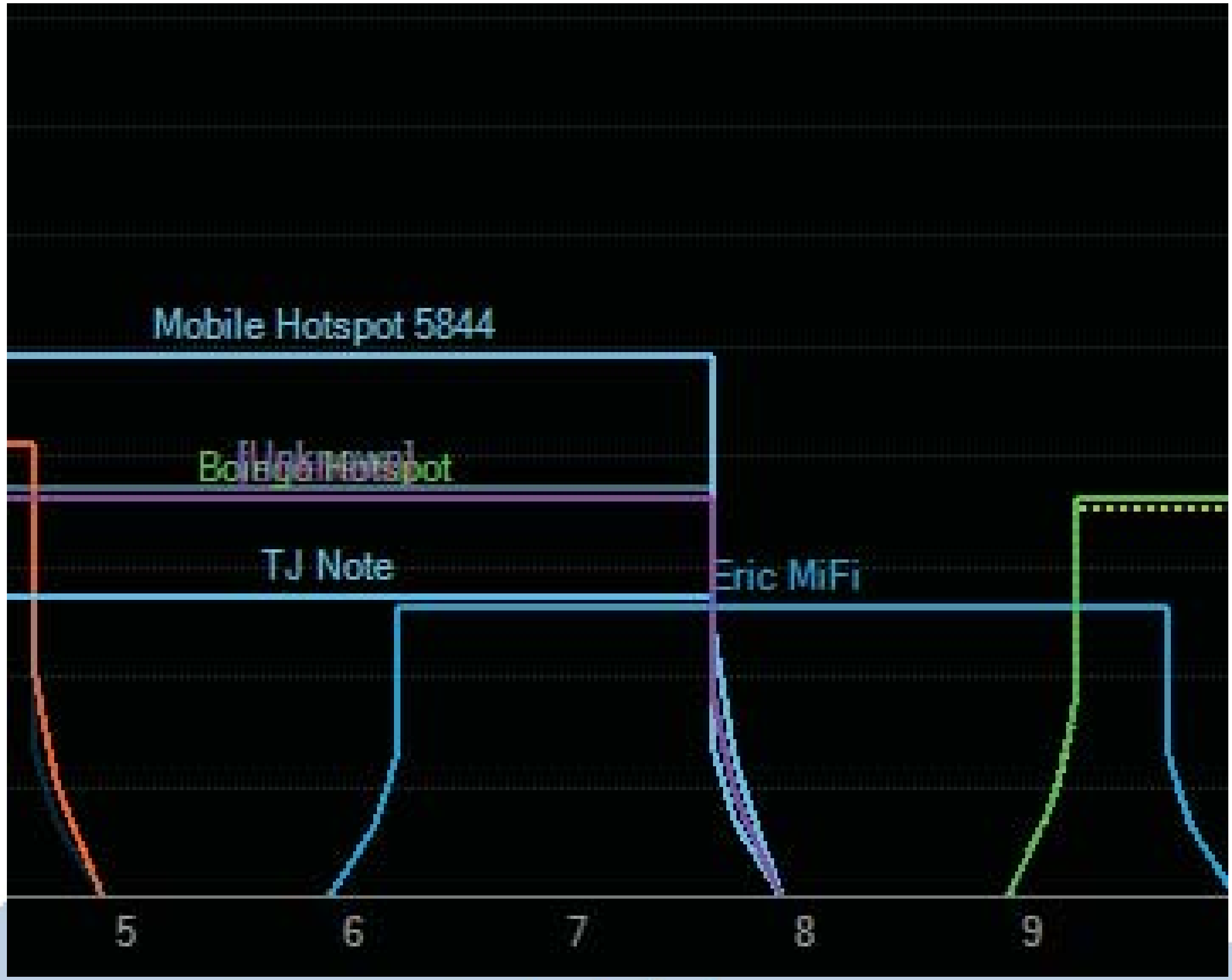
Key

0.00% – Less than 2% utilization

2-20% – 2% to 20% utilization

> 20% – More than 20% utilization

Impact of Hotspots & Ad Hoc Networks



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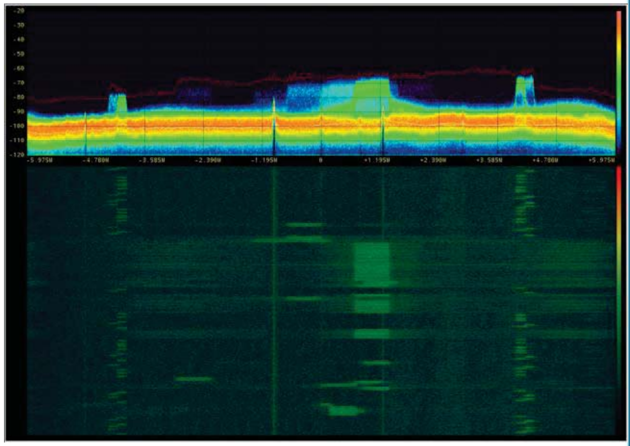
Automated Tools & Management

- Wi-Fi networks are too dynamic to manage manually
  - They require automated sensing and
  - New tools to manage them



- Software defined radio is providing a rich set of management tool
- Increasingly vendors are integrating these into their network products

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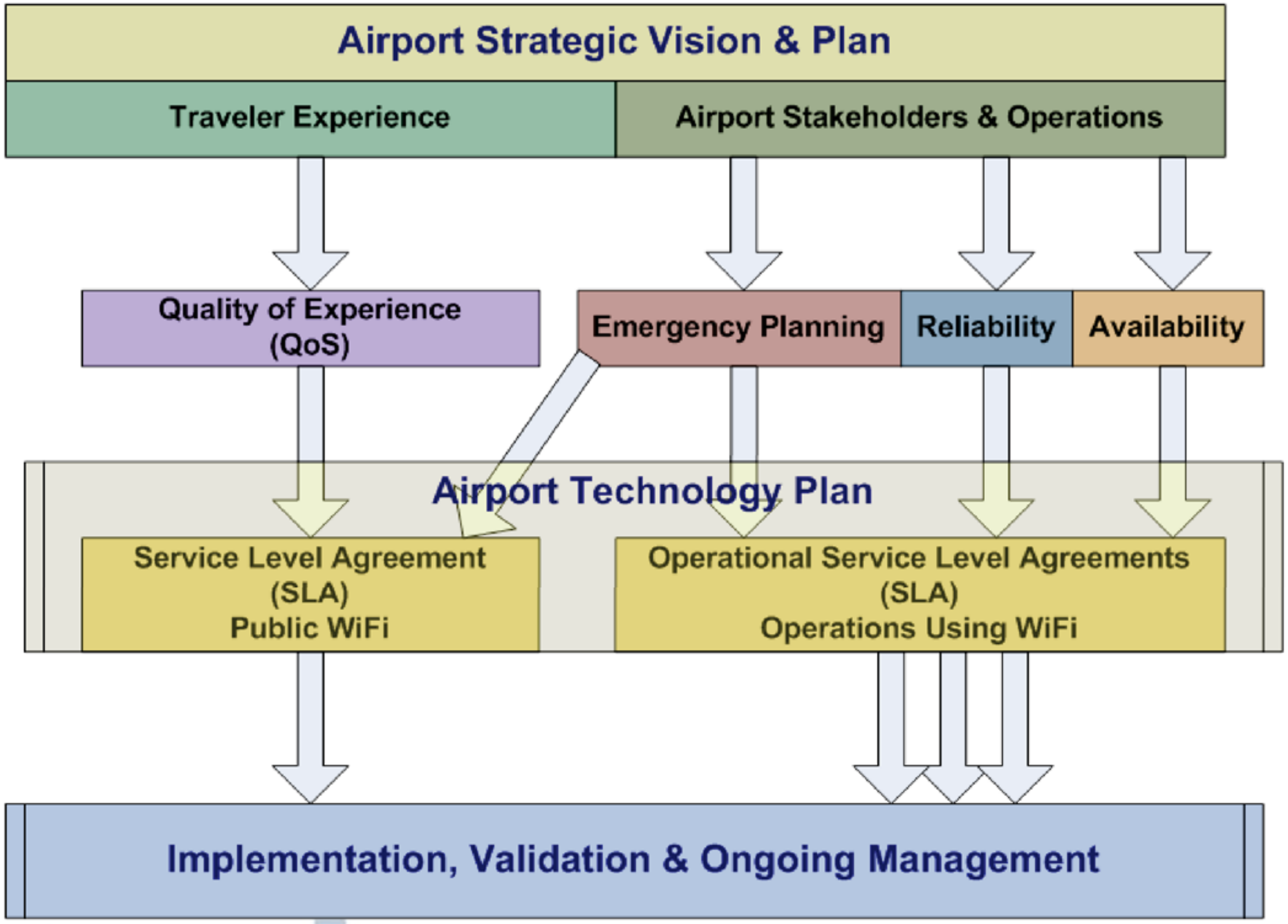
Strategic Planning for WiFi Networks

- Begins with an assessment and development of a robust network infrastructure
  - Existing systems
  - Future plans
  - Interdepartmental communication
  - Focus groups
  - Technology governance
- Develop an airport Strategic Plan
  - Similarities to public healthcare

    "The biggest mistake a healthcare delivery organization can make with wireless is failing to create a strategic plan on how to use and implement wireless technologies….Failure to create a foundational strategy increases the probability that the risks become adverse events."

AAMI Wireless Strategy Task Force, "FAQ for the Wireless Challenge in Healthcare," May 2014, question 4.

Sample Strategic Vision and Plan



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Service Providers Business Model

- Cellar business model:
  - Purchased dedicated “licensed” frequencies
  - Funded cost of establishing and operating networks
  - Subscribers provide funding to support the network
  - Decide and approve which devices are used on their networks; equipment certification process
- WiFi business model:
  - Operate in “unlicensed” spectrum
  - Networks are built in an ad-hoc manner; no single entity responsible for the network
  - Users determine which devices to bring to the airport; no regulated certification process before a device is marketed
  - Traveler expectation of free WiFi service at airports
  - Difficult to quantify user revenue source to support networks

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Stakeholder Relationships and Business Model Options

- Airport stakeholders must work together regarding wireless services
  - Passengers, businesses, and airport operations
  - Television and other media
  - Security (physical and network)
  - First responders
- Master service level agreements (SLA): a means to tie all these relationships together
  - SLA enforcement
  - Shared tenet services
  - Alternative revenue sources
- Business model

WiFi Network Operations – Solutions

- Airport managers need processes and tools in place to monitor the network and ensure satisfactory operation
  - SLAs are one way to address this issue for airport managers, network operators, and all stakeholders
  - Network analytics – processes are only as good as the feedback and control systems that enforce them.
  - System performance oversight – involves ascertaining whether the right level and amount of resources are in place and then evaluating whether those resources are being used effectively
  - Network management structure – one dominant WiFi provider and possibly a second cellular provider, or it may consist of multiple WiFi providers each with their own competing network
- Emerging trend – internet of things (IoT) or internet of everything
  - Growing trend for many devices to be continuously connected to the internet – primarily to extract and analyze data in real time
  - Requires proactive management and strategic planning – as IoT continues to increase it will bring make it easier for airports to better handle traffic flows and customer needs seamlessly, but also create the potential for new problems, interference issues, and unintended consequences that need to be managed

WiFi Operations at Small and General Aviation Airports

- Tend to be smaller, with typically simpler architectures, less traffic, and less dense requirements for WiFi services
  - Strategic plan is just as important even for scaled down wireless services with less available resources
  - Commercial publications are available that address the needs of small airports and can be tailored to meet requirements
  - One option is to build a system around a single carrier digital grid that enables high-speed broadband traffic that includes the airport proper and local community or town
  - SLAs can be used to define the stakeholder relationships, performance expectations, and cost sharing
- Process is similar to large airports
  - Identify the requirements
  - Quantify the desired service levels
  - Begin the design, time table for implementation, rough order magnitude for cost
- Establish and maintain data
  - Establish a database of problem reports and solutions
  - Take periodic measurements to assure performance

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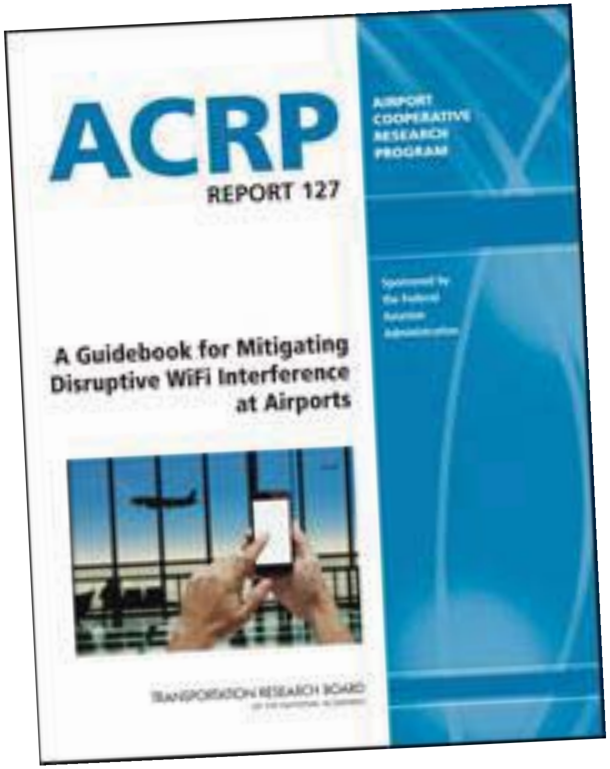
Conclusion – What Should Airport Managers Do?

- Remember primary airport WiFi interference is from other WiFi devices and passenger/stakeholder use cannot be restricted
- Will your business case take you into the future, does it mesh with your strategic plan, do stakeholders agree, and is it documented in some type of agreement?
- Consider making your network manager a strategic partner (not just a vendor); networks need to be periodically monitored, audited, and results compared to other networks and airports; and service providers require specialized skills to baseline and diagnose problems
- Does your crisis action plan include the WiFi network and appropriate security – loads change dramatically in any crisis situation

For additional information:



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http://www.trb.org/main/blurbs/172272.aspx

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Supplemental Slides

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Spectrum Congestion
Use of 2.4 vs. 5 GHz WiFi Channels

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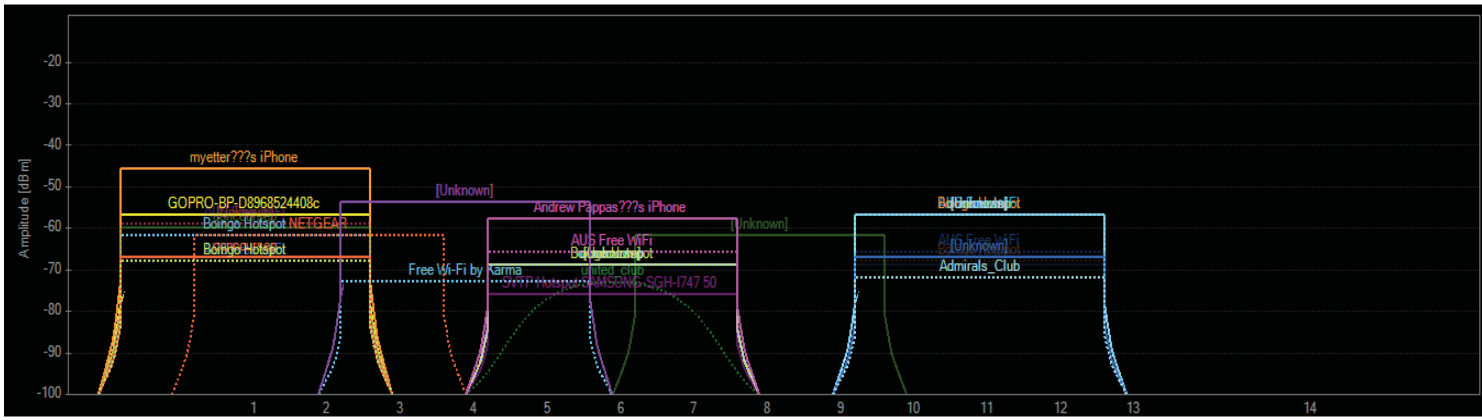
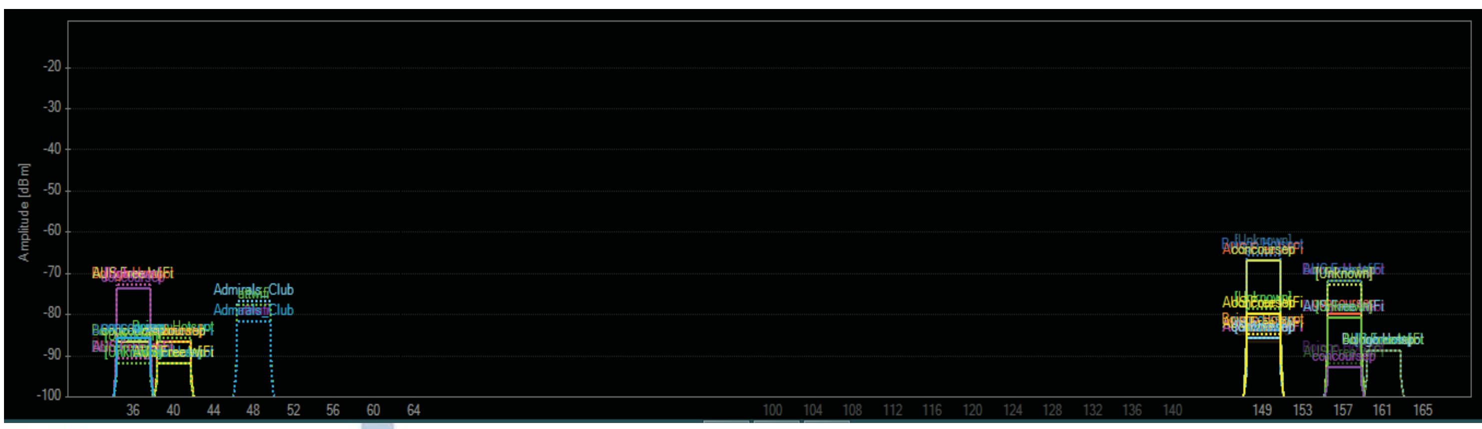
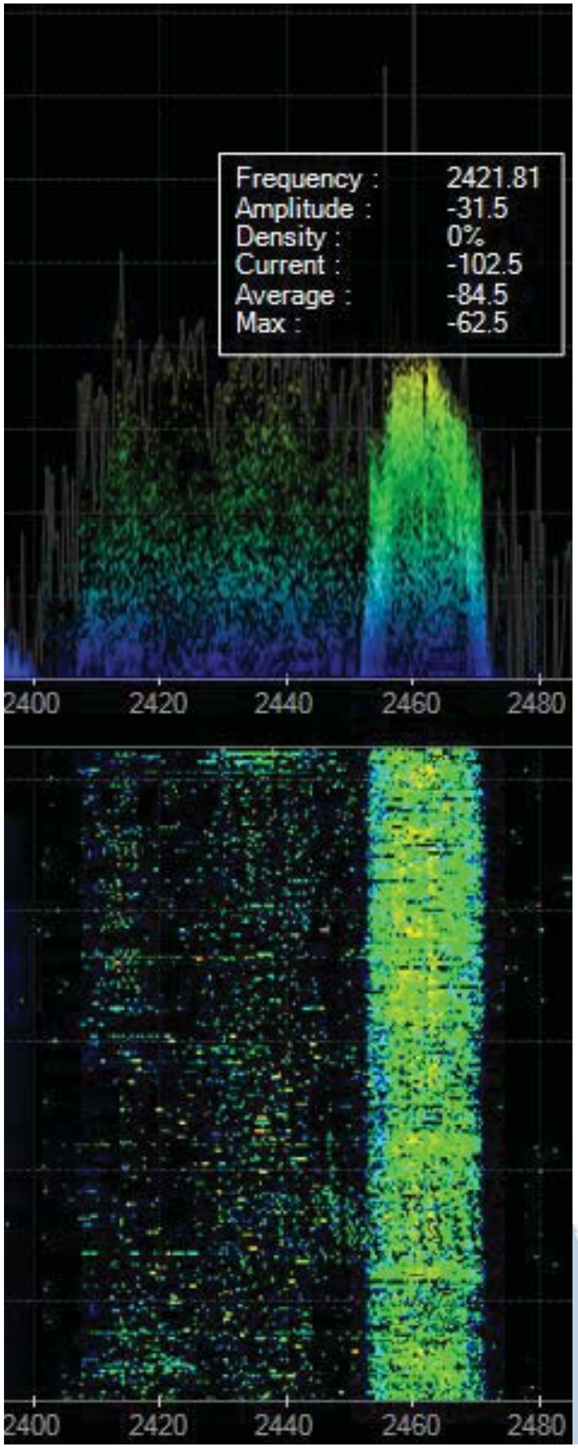
2.4 GHz

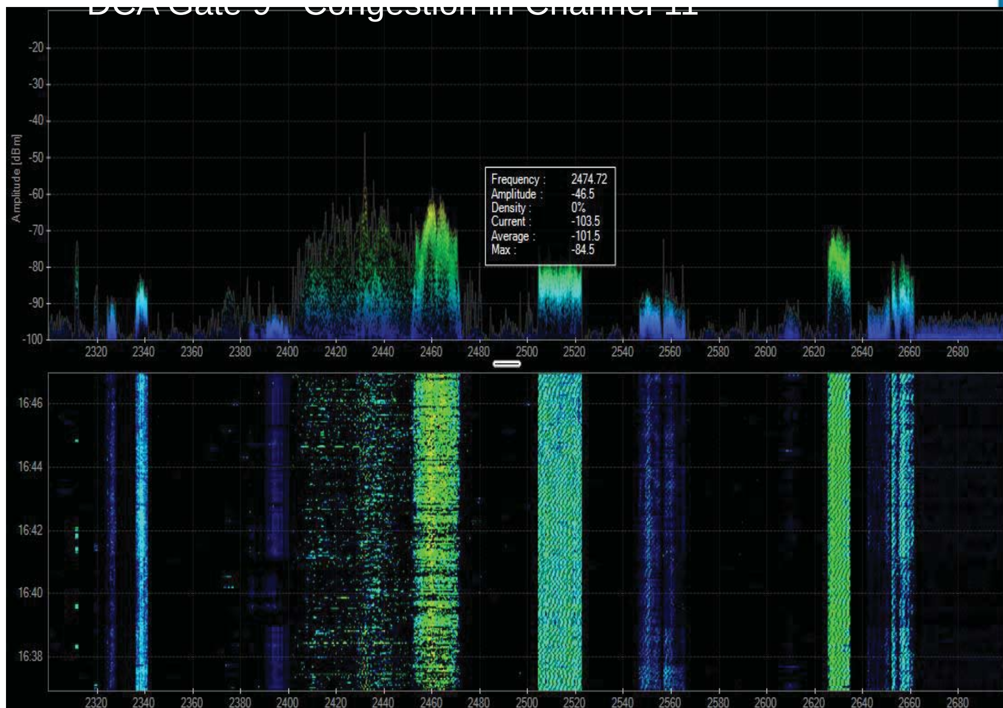


5 GHz



DCA Gate 9 – Congestion in Channel 11





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Traffic Distribution

Date (YR-MO-DAY)	Location	Most Used Channel	Band: 2.4 GHz ISM, WiFi Channels: 1-14	5.8 GHz Lower UNII, Indoor 36-48	5.8 GHz Lower UNII, DFS/TPC 49-64	5.8 GHz Middle UNII, DFS/TPC 100-140	5.8 GHz ISM 149-165
131122	Philadelphia Gate D1	45.43%	99.98%	0.02%	0.00%	0.00%	0.00%
131122	Philadelphia Gate A9	26.00%	93.30%	3.58%	0.00%	0.00%	3.12%
131122	O'Hare Gate K4	28.75%	70.15%	11.50%	0.00%	0.00%	18.36%
131122	O'Hare Gate H5	33.93%	69.73%	18.44%	0.00%	0.00%	11.83%
131122	O'Hare Gate H5	44.07%	73.64%	15.88%	0.00%	0.00%	10.48%
131122	O'Hare Gate H9	30.54%	66.86%	12.76%	0.00%	0.00%	20.38%
131122	Austin Gate 12	22.41%	41.18%	40.21%	0.00%	0.00%	18.60%
131211	Waco Terminal B	31.33%	100.00%	0.00%	0.00%	0.00%	0.00%
140107	Austin Gate 12	61.02%	75.66%	12.99%	0.00%	0.00%	11.35%
140107	Denver Concourse C Food Court	26.26%	92.05%	5.37%	0.00%	0.00%	2.58%
140107	Denver Gate C28	27.64%	91.76%	3.64%	0.00%	0.00%	4.61%
140112	Killeen Airport Food Court	42.39%	100.00%	0.00%	0.00%	0.00%	0.00%
140112	DFW Gate A36	73.16%	89.10%	0.01%	0.00%	0.00%	10.88%
140112	DFW Gate D20	67.14%	26.17%	73.83%	0.00%	0.00%	0.00%
140112	DFW Gate E21	51.53%	78.55%	0.22%	0.00%	0.00%	21.22%
140113	NSF Keck Center Room 110	82.23%	95.08%	4.92%	0.00%	0.00%	0.00%
140113	NSF Keck Center Room 110	87.19%	99.57%	0.33%	0.00%	0.00%	0.09%
140115	DCA Gate 30 & Food Court	38.84%	54.45%	12.03%	0.00%	0.00%	33.52%
140115	DCA Gate 27 & Food Court	57.30%	81.66%	0.08%	0.00%	0.00%	18.26%
140115	DCA Gate 25	89.95%	100.00%	0.00%	0.00%	0.00%	0.00%
140115	DCA Gate 28	74.77%	83.03%	16.97%	0.00%	0.00%	0.00%
140115	DFW Gate B18	65.20%	90.22%	0.09%	0.00%	0.00%	9.69%
140119	Austin near Terminal Door C3D	43.13%	73.79%	14.01%	0.00%	0.00%	12.21%
140119	Austin Gate 12	33.53%	46.16%	35.86%	0.00%	0.00%	17.98%
140119	DCA Gate 2	97.85%	100.00%	0.00%	0.00%	0.00%	0.00%
140119	DCA Gate 9	58.94%	68.61%	0.09%	0.00%	0.00%	31.31%
140119	DCA Gate 9	64.86%	70.75%	0.02%	0.00%	0.00%	29.23%

Key
0.00% – No traffic
< 45% – Less that 45% of total traffic
> 45% – More than 45% of total traffic

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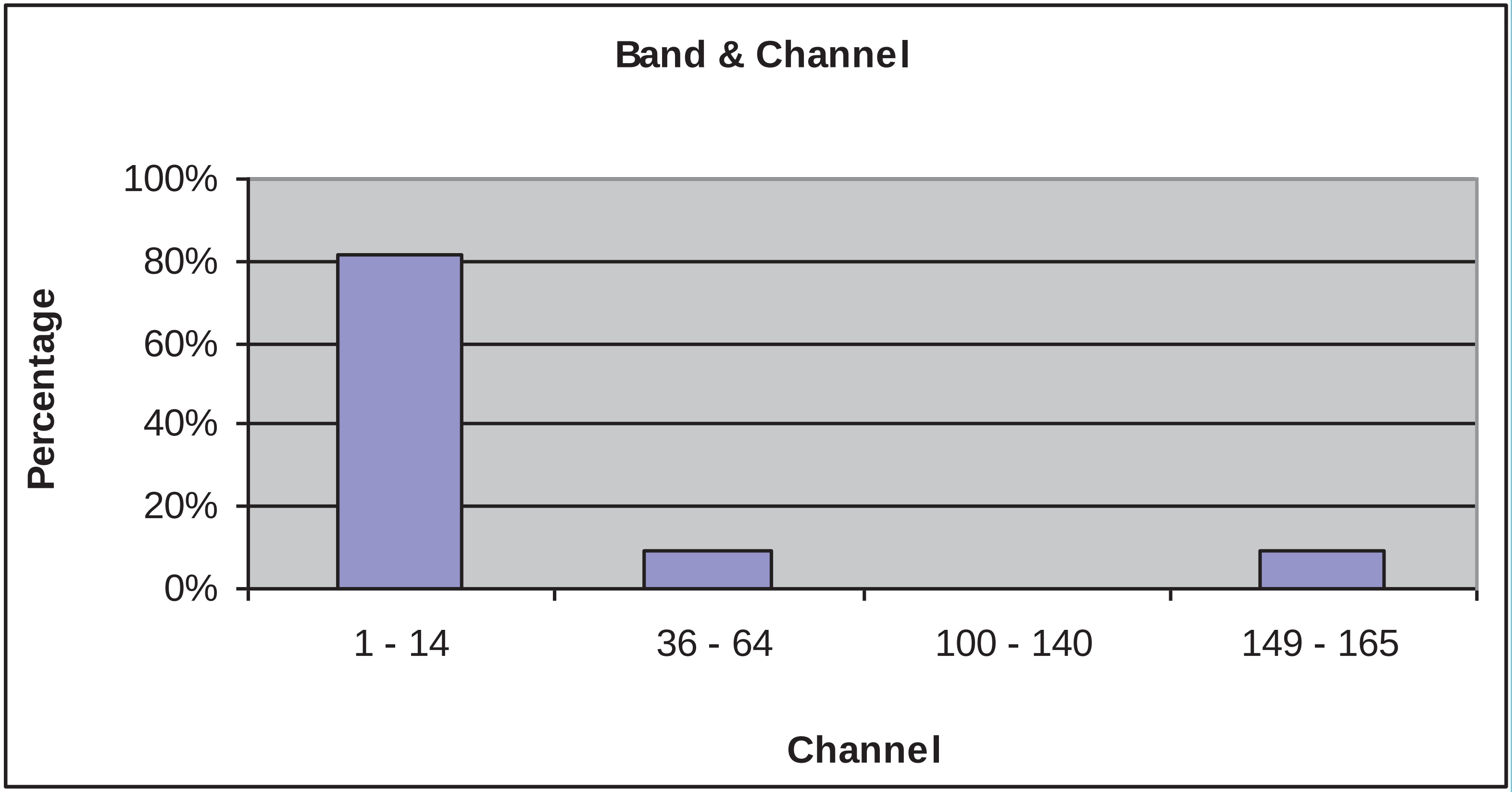
Band & Channel Distribution



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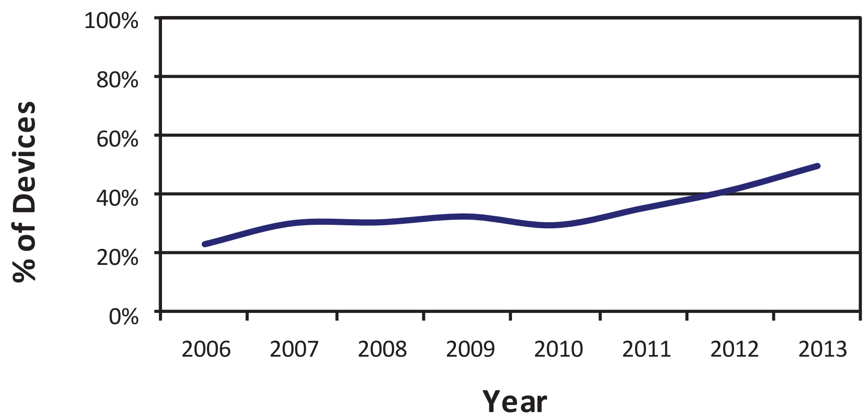
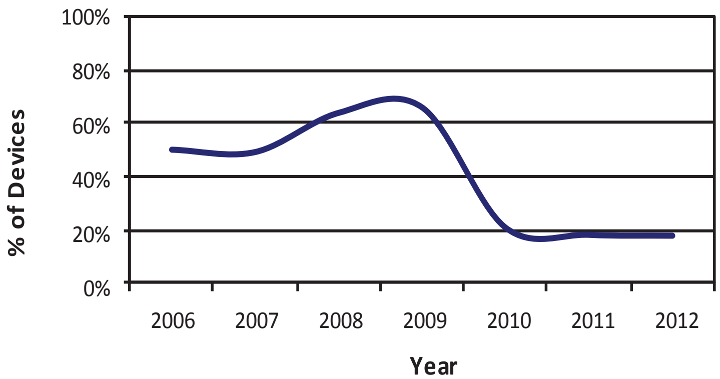
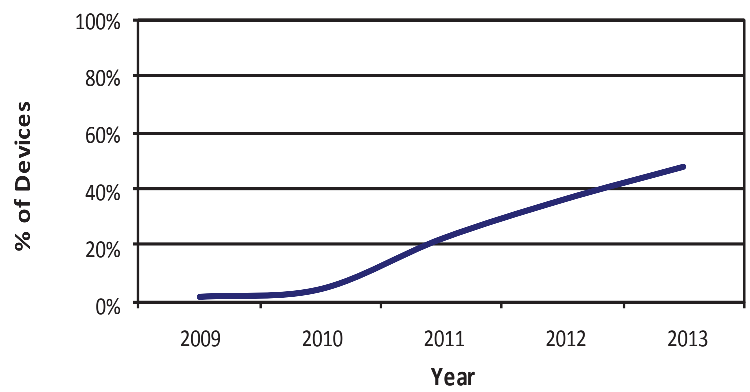
Dual Frequency Band Devices



Dual Frequency Band Laptops



Dual Frequency Band Smartphones



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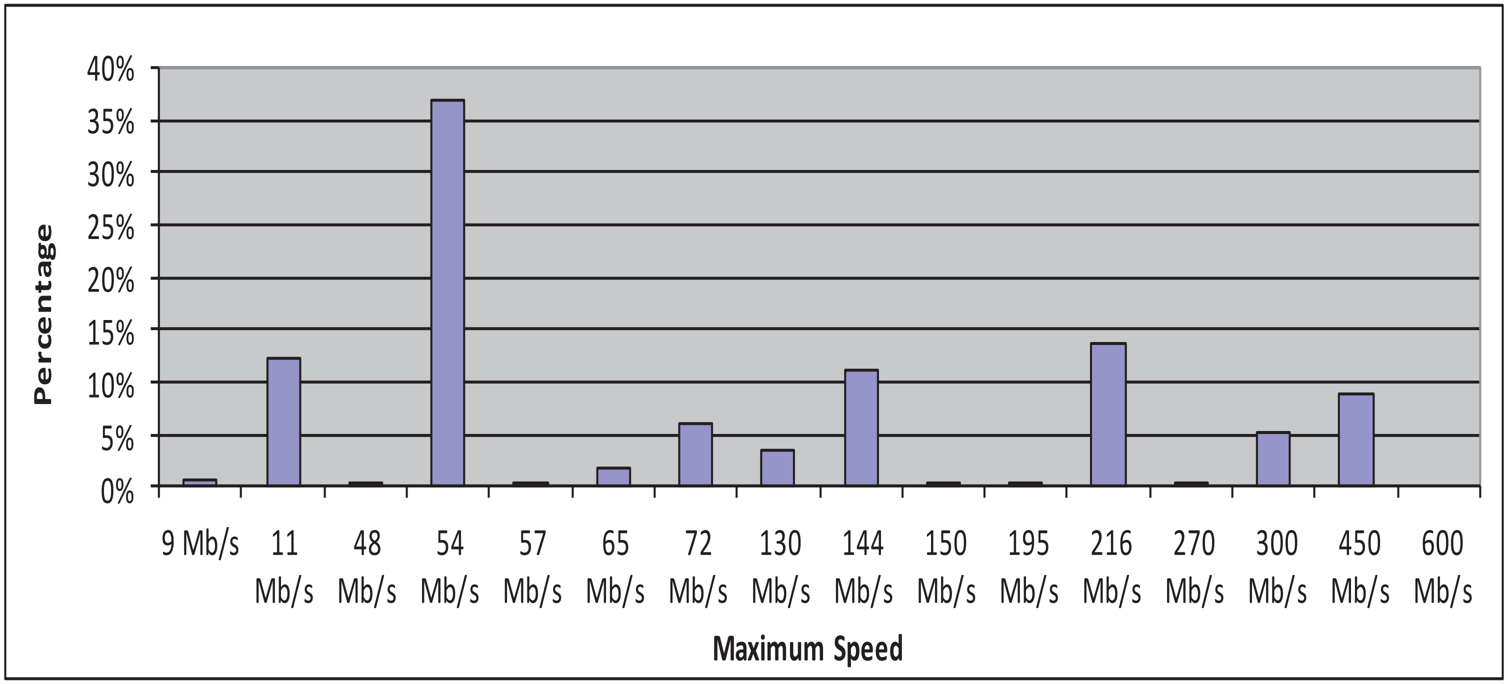
Microsoft Featured Products, October 2013

Total number of **tablets**:	4
Number that are dual band:	2
Percent that are dual band:	50%
Total number of **laptops**:	15
Number that are dual band:	6
Percent that are dual band:	40%
Total number of **all-in-ones**:	7
Number that are dual band:	2
Percent that are dual band:	29%

Airport Access Points Data Rates



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Access Point Loading

Name	Access Points	Total Devices Detected		Devices/AP
Atlanta Gate B26	40	530		13.3
Atlanta Gate F1	38	311		8.2
Atlanta Gate F7	37	512		13.8
Atlanta Gate F14	27	500		18.5
Austin Gate 6	30	338		11.3
Amsterdam Gate D83	22	295		13.4
Amsterdam Gate C5	92	596		6.5
Amsterdam Gate D64	30	236		7.9
Amsterdam Gate E8	75	361		4.8
Amsterdam Gate D2	32	216		6.8
Amsterdam Gate D61	26	486		18.7
Copenhagen Gate A2	41	301		7.3
Copenhagen Gate C4	85	564		6.6
Copenhagen Gate D1	35	211		6.0
Minneapolis Gate D4	32	370		11.6
Minneapolis Gate F1	34	315		9.3
Denver Gate C40	24	353		14.7
Minimum	22	211		4.8
Maximum	92	596		18.7
Average	41.2	382.1		10.5
Standard Deviation	22.9	150.6		4.9

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